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THE PRIMEVAL OCEAN.

BY CHARLES MORRIS.

In dealing with the conditions of the remote past it is impossible to avoid hypothesis, since exact knowledge is not within our reach. The best that can be done is to support hypothesis, as far as possible, with facts drawn from experimental science. It is only in this way that we can deal with the problem of the Primeval Ocean, by seeking evidence for speculative conception in existing facts. The views which are entertained, for instance, concerning the former greatly heated condition of the earth, which must largely affect any hypothesis concerning the ocean, are mainly speculative. Yet there are so many facts to sustain them that they are generally accepted as well founded; and if we accept the view that the earth has gradually cooled to its present state from a former greatly heated or vaporized condition, certain conclusions concerning the former state of the ocean and atmosphere become inevitable.

At one time, under such circumstances, there could have been no ocean, since all the water of the earth must have existed as atmospheric vapor. Still more remotely, perhaps, no water existed, the temperature being too high for that combination of oxygen and hydrogen to which it is due. Such a condition probably exists now in the solar spheres, whose atmospheres contain an abundance of free hydrogen.

As regards the oceanic and atmospheric conditions of an earth chemically like the one we inhabit, but differing from it greatly in temperature, there are certain conclusions which appear inevitable. If, for example, the surface of the earth should become so heated as to raise the oceanic waters to the temperature of 212° F., that is, to the boiling point under present atmospheric pressure, there would result a very considerable evaporation of the waters of the ocean, but by no means a total one. In fact, the great bulk of the ocean would remain in its bed, since the pressure of the atmosphere would be much enhanced by its increase of aqueous vapor, and the boiling point of water be correspondingly raised. Therefore, during the ancient cooling of the earth, the aqueous vapor of the atmosphere must have begun to condense into water long before the temperature

sank to 212°, and the earliest ocean must have formed at a much higher temperature.

We have experimental evidence of the boiling point of water under pressure up to a certain limit of temperature. Under a pressure of one atmosphere, as is well known, water boils at 212° F. With increase of pressure the boiling point rises, but not in an equivalent ratio, since the energy of evaporation increases more rapidly than that of pressure. For example, under five atmospheres of pressure water boils at about 300° F.; under fifteen atmospheres it boils at about 400° F.; under twenty-five atmospheres it boils at about 440° F. I have given approximate temperatures, so as to state them in round numbers, the actual temperatures differing slightly from those stated.

It is evident from the figures given, that as the temperature rises the energy of evaporation steadily gains the ascendancy over that of pressure. At 300°, one hundred degrees of temperature must be added to produce ten additional atmospheres of pressure. At 400° only forty degrees of temperature are needed for the same result. Experiment has gone no further, and we are not aware at what rate the temperature of the boiling point would increase under higher pressures. But if we may judge from the rapidly accelerated increase of evaporative energy with increase of temperature, it may be that at some point between 600° and 800°, all the waters of the ocean would be converted into vapor and form part of the atmosphere.

At the boiling point of 440°, which yields twenty-five atmospheres of pressure, one-twelfth of the oceanic waters would be converted into vapor, and eleven-twelfths continue as water. A total evaporation of the oceanic waters would produce a pressure of about three hundred atmospheres, or 4,500 pounds on each square inch of surface. The primeval pressure must have been still greater, since much water which has sunk into the earth's crust and forms no part of the present ocean must then have added to the volume of atmospheric vapor. We cannot affirm at what limit of temperature this great pressure would be overcome, but, from the rapid rate of increase in evaporative energy observed between one and twenty-five atmospheres of pressure, it seems not improbable that this limit would be reached, as above said, at some point between 600° and 800°.

At the period in question, when all the ocean was in the air, the enormous pressure must have exerted an important influence

upon the surface conditions of the earth. There may have been then a very active tendency to volcanic or earthquake disturbances, but this tendency must have been held greatly in check by the pressure. This great pressure must also have exerted a vigorous influence in condensing surface and aerial materials, converting vapors into liquids and liquids into solids, and thus have played its part in the formation of a solid crust. Again, the abundant aqueous vapor must have been active in the process of surface cooling, rising in heated winds and conveying heat to the upper air. Finally, as the temperature fell, the pressure of the vapor condensed some of its own material into water. The escape of heat then grew still more rapid, through the aid of evaporating water and falling rain, processes which may have long been incessant.

As the surface cooled, through these and other influences, the conversion of vapor into water went on more rapidly, and the atmospheric pressure steadily decreased. This was probably attended with an increase in surface disturbances, the wave of disturbance growing in height as the pressure diminished. As the solid crust grew thicker and the rocks more rigid from progressive cooling, these seismic disturbances again diminished. There was thus probably a cycle of change, from an originally level and quiescent surface to one of ridges and depressions with great disturbance, and again to one of growing quiescence and gradual reduction of inequalities.

Of the chemical activity of water at a temperature of over 600° we have no knowledge, as water of this temperature has not been produced in laboratories under circumstances suitable for experiment. Its solvent powers would probably be very great, and many substances may have been held in solution in the waters of the primeval ocean which are insoluble at present temperatures. These substances were, probably, in part washed down from the air into the gathering ocean, in part dissolved from the surface. The bringing together of numerous elementary substances or simple compounds in a common menstruum was undoubtedly followed by great chemical activity, and numerous compounds of more or less intricacy were formed in the heated waters. Of these, some were insoluble and settled to the bottom ; others were soluble and continued in solution. The salts of the present ocean are doubtless, in great measure, the final outcome of these ancient solutions and chemical actions. They, in all probability, represent but a small fraction of the substances

then held in solution by the heated oceanic waters, which, from their large percentage of foreign constituents, may have been almost jelly-like in consistency.

It is impossible to estimate the chemical activity of that period. The high temperature of the waters greatly favored such action, and among the dissolved substances were probably many unoxydized materials, now first freely exposed to the assaults of oxygen. The energy of chemism that ensued was probably greater than had ever before or has ever since existed. In addition to simple oxides, many more complex substances were doubtless formed, and it may be that many of the constituents of the primeval rocks then and thus first came into existence.

The story of chemical activity in the earth is, therefore, very closely connected with that of the ocean. It began, no doubt, in the primeval atmosphere, but reached its culmination in the waters of the ocean. During the early period of the earth chemical inaction must have long prevailed, on account of high temperature and unfavorable physical conditions. Perhaps the principal chemical action of the primeval atmosphere was the combination of oxygen and hydrogen into water vapor. But, on the formation of an ocean of highly heated waters, holding in solution a considerable variety of elementary substances and simple compounds, chemism probably grew active, and in time became very energetic as the waters increased in depth and in the variety and volume of their contents. Many of the complex minerals were very likely then formed, and, being insoluble, were separated from the water and deposited as rock formations. Only when the ocean became, in a measure, freed from its abundance of foreign material, did this activity of inorganic chemistry decrease. It has continued to decrease until the present time, when it has practically ceased to exist, oxidation having reduced nearly all substances to a state of chemical fixity.

It has been succeeded by an era of organic chemical action, which is, at present, in a state of full activity, and promises long to continue so. It began in the early seas, probably after their temperature had diminished to near or below the present boiling point. It gradually replaced inorganic chemism, and has long continued active, at first in the water, and later on the land also. It is now, and has long been, at its maximum activity, the quantity of new material produced in the plant and animal world being annually enormous.

Continued refrigeration must, in time, repress this organic activity and bring it finally to an end, the chemical inertness once due to extreme heat being paralleled by a similar inertness due to extreme cold. The interval between is that of the earth's chemical history. In the history of chemistry we perceive, therefore, two great cycles, an inorganic one whose principal feature is oxidation, which reached its culmination in the remote past, and an organic one, whose principal feature is deoxidation, which is now at its culminating point.

The question which naturally follows is: When did inorganic activity cease, and organic activity begin, and to what extent is the latter an outgrowth from the former? The reduction of the temperature of the ocean had much to do with this change, inorganic action being probably favored by a high temperature, while organic action may have been impossible in waters much above 212°. These two phases of chemical activity differ strikingly in one particular. Inorganic chemism had a fixed period of duration, beyond which it could not exist. When there remained no more substance in condition to be seized upon by oxygen, this phase of chemical action necessarily ceased. Organic chemism has no such limitation. It may continue in activity, under favorable conditions of temperature and sunlight, indefinitely, its material being practically inexhaustible. Only decrease in temperature can bring it to an end.

As the waters of the primeval ocean slowly cooled, and inorganic chemism declined in activity, organic chemism probably set in, aided by the solar rays, then perhaps first freely reaching the waters. The material for this new phase of action had been prepared before and existed abundantly in the water and air. It may have had its origin in an early reaction between carbon dioxide and the elements of water, yielding the hydro-carbons; and subsequently between these and nitrogen, yielding the far more complex albuminous compounds.

Certainly organic forms appeared in the waters of that period, and conditions favoring their formation must have existed. We do not know through what successive steps of chemical combination the complex organic molecules arose. We do know that many of the preceding mineral molecules were quite complex in composition, and can reasonably deduce from this that still more complex molecules arose under conditions restraining the activity of oxygen. Seed forms of organic substance may have first appeared—simple carbon compounds. These would serve as the basis of more complex

molecules, and there may have been a long-continued process of de-oxidation and formation of higher carbon and nitrogen compounds, till true organic matter appeared and the chemistry of life came fairly into play.

I have but one further suggestion to offer. That is, that the conditions favoring the development of organic material were transitory, and no longer exist. If living matter were now swept from the earth, it could not, in any probability, be restored. Its seed conditions have passed away. They could not reappear in water of the temperature of the present ocean and the existing chemical relations of inorganic matter. Organic chemistry emerged from a vitally active stage of inorganic chemistry. It could not well arise from the existing passive stage of inorganic chemistry. Fortunately, conditions favoring the origin of organized matter are no longer needed. Organisms have within themselves the power of inducing new chemical action to an indefinite extent. A plant is a natural organic laboratory, within which new organic material is elaborated from elementary constituents which exist abundantly in air and water. From the plant the animal derives the more complex material it requires. Thus the process goes continually on, and can only be brought to an end by a fall in temperature below the point requisite for organic chemism. How far in the future this will be it is impossible to predict, but the reign of life, which has continued for many millions of years upon the earth, will, in all probability, continue for many millions of years to come.